Journal of Philosophical Theological Research
Print: 1735-9791
Online: 2538-2500

The Laws of Nature and Creation of the Universe *ex Nihilo*

Mirsaeid Mousavi Karimi

Associate Professor, Department of Philosophy, Mofid University, Qom, Iran.
msmkarimi@mofidu.ac.ir

Research Article

Abstract

The idea of "*creatio ex nihilo*" entered the arena of natural science with the advent of modern cosmology in the mid-twentieth century. This idea, that is, the creation of the universe out of nothing, seems to be a consequence of the widely accepted Big Bang Theory which implies the temporal finitude of the world. In order to avoid the theological and metaphysical implications of such an idea, some scenarios and scientific models have been proposed. According to one of the scenarios, the *creation ex nihilo* of the world is a causal physical phenomenon, and, hence, can be explained scientifically by appealing to the laws of nature. In this essay, I aim to discuss and criticize this idea. To fulfill this aim, in the introduction some achievements of modern cosmology will be very briefly introduced. In the next three sections, the notions of existence and nothingness, creation, scientific explanation, and singularity will be explored. It will be shown that what philosophers mean by these notions isradically different fromthe naïve ideas of some scientists. Hence, applying these notions to physical models of the origin of the universe is completely misleading. This work concludes that no scientific explanation appealing to the laws of nature can possibly explainthe creation of the universe out of nothing.

Keywords

Big Bang, *creatio ex nihilo*, laws of nature, singularity, existence.

Received: 2022-12-02 ; **Received in revised form:** 2023-02-16 ; **Accepted:** 2023-02-25 ; **Published online:** 2023-02-27

▣ Mousavi Karimi, M. (2023). The Laws of Nature and Creation of the Universe ex Nihilo. *Journal of Philosophical Theological Research*, 25(1), 75-100. https://doi.org/10.22091/jptr.2023.9034.2841

Introduction

It is now a widely accepted view that modern cosmology started in 1917 when Einstein tried to apply the theory of general relativity to the universeasawhole. In the 1920s and 1930s, several cosmological models, based on Friedmann's solution of Einstein's equations, predicted the expansion of the universe.

Should the course of world expansion be reversed, we would have reached a space-time singularity. Indeed, Stephen Hawking (Hawking & Ellis, 1965) and Roger Penrose (1965) argued that the existence of the initial singularity seems inexorable.

Initial singularity is a state in which the material density, the temperature, and the space-time curvature of the universe are infinite. Indeed, singularity demonstrates the temporal finitude of the world. The temporally finite universe, most physicists believe, must have been created out of nothing some billions of years ago. I should clarify that by "universe" I mean everything whose existential source is the initial singularity, including the singularity itself. "Everything" then includes all entities, their properties, and relations with each other, laws of nature, etc. which have appeared since the Big Bang. By this definition, therefore, I preclude God, non-physical eternal entities, platonic worlds of abstract entities, pre-existing worldsbefore the singularity,[1] and such alike, if there are such entities and existents. In sum, the temporal finitude of the universe implies that "we would truly have a *creation ex nihilo*" (Barrow & Tipler, 1996, p. 442).

The *creatio ex nihilo*, however, seems to be a problematic notion for cosmologists; the problem is, why didthe universe come into existence if there was not anything as the cause of the event? To solve or dissolve this problem, scientists have thought of somemodels andscenarios.[2] According toone of the scenarios, the *creatio ex nihilo* of the world is a causal physical phenomenon, and, hence, can be explained scientifically by appealing to the

1. Accordingly, I put aside some physical models such as oscillating worlds, loop quantum cosmology, and string theory, which assume pre-Big Bang worlds from which our universe has emerged. According to these models, what happened some billion years ago was the creation of the universe from something, not out of nothing. See also the next footnote.
2. The most important scenarios and models are: the Steady-State Theory (Bondi & Gold, 1948; Hoyle, 1948; 1975; 1992; 1994; Bondi, 1961; 2010); Cyclic Cosmologies (Penrose, 2010; Steinhardt & Turok, 2007), Loop Quantum Cosmology (Rovelli, 2010; Bojowald, 2010) & String Theory (Gasperini, 2008). None of these models and scenarios is popular today. There is either no experimental evidence supporting them or there is indeed strong experimental evidence against them (Brush, 1992: 40 & G. Ellies, 1993: 68).

laws of nature.[1] In this scenario, the laws of nature are considered as entities that have ontological powerand brought the universe into existence some billions of years ago. In this paper, I aim to discuss and criticize this idea.[2]

It is worth mentioning that the aim of this paper is not to show that modern physics supports the idea that divine creation best explains the existence of the universe. In effect, as Kragh (2023) rightly asserts, "[t]here simply is no and was no one-to-one correspondence between views about cosmology and views about religion." Rather, the paper merely tries to demonstrate that all physical models proposing the *creatio ex nihilo* of the universe are based on a radical misunderstanding of the notions of nothing, existence, and creation. In other words, what philosophers and theologians mean by these notions is totally different from the meaning of these notions in modern cosmology. Accordingly, philosophical and theological theories of creation, on the one hand, and physical theories of the emergence of the universe, on the other hand, are not competing theories. Hence, many theologians believe that all physical cosmologies, whatever they are or can be, completely accord quite well with the traditional theistic idea that God created and always sustains the universe continuously. For, from the Jewish, Christian, and Muslim philosophers' and theologians' point of view, the universe in its totality is indeed a contingent entity and hence needs an agent cause as its creator and sustainer. In effect, according to the Abrahamic theologians' opinion, without the grace of God, the world with everything within it will be destroyed immediately and fall back into nothing since the world in its totality is ontologically dependent on God (see, e.g., Ibn-Sina, 2000, vol. 3, pp. 2-28; MullaSadra, 1981, vol. 2, pp. 212-219, vol. 3, pp. 244-278 & vol. 5, pp. 194-246; Isham, 1992; Drees, 1988, 1990 & 1991). On the basis of such view, the Christian philosopher and theologian, Thomas Aquinas "distinguished between a temporal beginning

1. For example, see the Tryon-Vilenkin and Hawking-Hartle (1983) models. For more discussion on the second model, see Craig & Smith (1995), Deltete & Guy (1997), Craig (1997), and Smith (1998). It can be said that Grünbaum's (1991, 1994) idea that the temporal finite universe always existed, and Smith's (1988, 1994a, 1994b) claim that the creation of the universe is a spontaneous uncaused origination *ex nihilo*, areindeed the philosophical interpretations of these models.
2. Contrary to the Big Bang model which proposes the creation of the whole universe at t=0, its unsuccessful rival theory, that is, the Steady-State model, assumes the continuous creation of new matter. Although this is a dead theory now, Grünbaum (1989, 1991, 1993, and 1998) has interpreted it in such a way to show that the continuous creation of matter in this theory is not a case of *creatio ex nihilo*; rather is a physical phenomenon which can be explained scientifically by appealing to the laws of nature. For a critical evaluation of this interpretation, see Mousavi Karimi (2011).

of the universe (creatio *originans*) and its creation, where the latter and theologically more fundamental concept referred to the existence of the universe as such" (Kragh 2023).

So, the aim of this paper is to show that the creation of the universe out of nothing cannot be explained by merely appealing to physical laws. In effect, none of the proposed scientific models to explain the *creatio ex nihilo* of the universe have hitherto succeeded. For, all of them are various formulations of the creation of something from something or changing of something to something. For example, the two best and most important physical models in this area are Hawking-Harle and Tryon-Vilenkin models. They are based on quantum phenomena such as quantum vacuum fluctuation[1] for explaining the creation of the universe out of nothing.

Tryon (1973) was the first to use the quantum fluctuation phenomenon to explain the emergence of the universe out of nothing. His model, however, could not explain why the universe has become so large. An improved extension of Tryon's Model was proposed byAlexander Vilenkin (1982, 1982 & 1986). By using the idea of quantum tunneling as the first state that exists and there was no time before that, and its combination with the idea of the plasticity of space from general relativity, Vilenkin (1983, p. 2848) claimed that his version of the inflationary scenario can explain the spontaneous creation of the world from nothing.

The problem, however, is that in this model, by nothing, Vilenkin (1983, p. 2851) means "a state with no classical space-time", though he "presupposed a fuzzy quantum space-time background that the universe tunneled *from*" (Kragh, 2007, p. 241, italics original). In effect, Vilenkin (1983, p. 2850) supposes that before the instant of the creation, there were Higgs fields and that they "have several components."Moreover, a quantum vacuum is a sea of continually forming and dissolving particles that borrow energy from the vacuum for their brief existence. A quantum vacuum is thus far from nothing. Hence, Vilenkin (2006, p. 185) finally accepts that the "vacuum" is very different from "nothing". This model indeed explains the transformation of something into something and not the creation of something out of nothing.

In the Hawking-Hartle Model, since the universe has no boundaries in space or time, "one can interpret the functional integral over all compact four-geometries ... to arise from a zero three-geometry, that is, a single point. In

1. Quantum fluctuation is an uncertain change in one of a system's parameters such as momentum or energy, which occurs in the world of subatomic particles according to the laws of probability.

other words, the ground state is the amplitude for the universe to appear from nothing" (Hartle & Hawking, 1983, p. 2961). This model assumes that at the initial singularity, the total sum of the positive energy of the motion or the matter and the negative gravitational energy matched zero. Accordingly, if the sum of the total energies of the universe is zero, then the creation of matter from pure energy (i.e., the emergence of the universe), is a type of *creatio ex nihilo*.

Similarly, Alexander Vilenkin (2015) writes that: "Modern physics can describe the emergence of the universe as a physical process that does not require a cause. Nothing can be created from nothing, says Lucretius, if only because the conservation of energy makes it impossible to create nothing [*sic*; something?] from nothing… There is a loophole in this reasoning. The energy of the gravitational field is negative; it is conceivable that this negative energy could compensate for the positive energy of matter, making the total energy of the cosmos equal to zero. In fact, this is precisely what happens in a closed universe, in which the space closes on itself, like the surface of a sphere. It follows from the laws of general relativity that the total energy of such a universe is necessarily equal to zero... If all the conserved numbers of a closed universe are equal to zero, then there is nothing to prevent such a universe from being spontaneously created out of nothing. And according to quantum mechanics, any process which is not strictly forbidden by the conservation laws will happen with some probability … What causes the universe to pop out of nothing? No cause is needed … No cause is needed for the quantum creation of the universe." Vilenkin claims that this scenario can explain how the universe could come into being from literally nothing.

The Hawking-Hartle Model, like the others that have attempted to describe the creation of the universe from nothing, is highly speculative and without experimental evidence. In effect, this model "is ad hoc in the sense that it does not flow from a more comprehensive unification of general relativity quantum theory" (Halvorson & Kragh, 2021)

At any rate, it is not hard to show that Hawking's and Vilenkin's analysis of the creation of the world out of nothing is untenable. Saying that if the addition of two energies equals zero, then they represent nothingness, is similar to saying that since the subtraction of one number from an equal number equals zero, then the numbers are the demonstration of nothingness. This is indeed a misrepresentation and misunderstanding of the notion of nothing. As the famous quantum cosmologist, Christopher Isham (1994), rightly points out, even if on balance the sum of the positive and negative energy of the world is naught, there still needs to be "ontic seeding" to create the energies in the first place.

Also, aswe explained already, the quantum mechanical vacuum not only is

not truly "nothing" but has a rich structure. The fact of the matter is that the Hawking-Hartle Model only represents the law of conservation of matter and energy. This model surely does not explain the *creatio ex nihilo*, but rather merely shows something comes out of something (see also Deltete & Guy 1997 & Craig 1997). As Grünbaum (1991, p. 233) rightly points out, "such physicists as Hartle and Hawking (1983) and Vilenkin (1983) speak misleadingly of certain primordial physical states as 'nothing'".

Moreover, both Hawking and Vilenkin assume that if there were nothing, then the physical laws would still hold, and these laws can somehow create the universe. Stephen Hawking (2010, p. 180) in his *The Grand Design* argues that because of the law of gravity, the universe can and will create itself out of nothing. So, there is no need for a Creator since science can explain the existence of the universe. But this reasoning is based on a misunderstanding of the concepts of nothing and creation. Let us assume that this highly questionable claim is accepted that in the absence of anything at all, the laws governing our universe would exist somehow independently and as abstract entities. However, by saying "because of the existence of laws of nature, " Hawking is assuming that there is something pre-existent, so this is not the *creatio ex nihilo* of the world.[1] Moreover, in the continuation of this paper, it is shown that such abstract entities can neither play the role of the material cause nor the efficient cause of the world. It will also be shown that what physicists mean by creation is indeed a kind of change of something, whereas, from philosophers' and theologians' points of view, creation assumes no pre-existent entities that undergo a transformation. Hence, creation is not a change; rather it is about bringing something to existence out of absolute nothingness, and explaining why there is something rather than nothing. Moreover, most theologians believe that the universe is continuously created, and by this, they mean the ontological dependence of the world on the Creator, rather than its temporal beginning.

Regarding the above introductory points, the paper is going to show that the naive idea of explaining the *creatio ex nihilo* of the universe by appealing to physical laws indeed contradicts itself. Accordingly, such a phenomenon can neither be driven from the laws of nature nor can be explained scientifically by appealing to the laws of nature. To reach this aim, by analyzing the notions of existence and nothingness, creation, and scientific explanation, it will be shown that any model for explaining the creation of the universe out of nothing by appealing to the laws of nature is untenable. This would be the

1. For a detailed and critical evaluation of the models proposed by Hawking-Hartle and Tryon-Vilenkin, see Mousavi Karimi (2023).

case even if the laws of nature are considered as independent abstract eternal entities which, in addition to their physical instantiations, exist somewhere independent of the physical world. This means that *creatio ex* nihilo of the universe out of nothing either (1) should be considered as an unexplainable, spontaneous, and uncaused event (a brute fact), or (2) it can only be explained metaphysically by appealing to some external causes. Whether the external cause is God, immaterial Platonic entities, or anything else is also a matter of further philosophical and not scientific discussion.

Existence and non-existence

It seems to clarify the meaning of non-existence, we first need to have a clear concept of existence. The problem, however, is that there seems to be no way at all in which we can explain the meaning and definition of "existence". Of course, we can probably explain the term "exists" by exploring its place in a network of concepts. However, asMunitz (1974) argues, it seems to be impossible to analyze the notion of existence by exhibiting it as made up of some more fundamental or simpler elements. Therefore, I assume that the concept of existence is a primitive and fundamental concept such that it is ultimately simple and unanalyzable. Descartes (1984/1991, 2, p. 418) was indeed right when he wrote "there is no need here for a definition [of existence], which would confuse rather than clarify the issue". Hence, I assume that everybody understands, more or less, the notion of existence.

Likewise, I assume that the notion of non-existence, like the notion of existence, is unanalyzable. I only emphasize that, ontologically, non-existence is absolutely non-existent. Nothingness is not a state, an event, a situation, or a non-existent thing, whether actual, potential, possible, or impossible. Nor is it an abstract, fictional, mental, or hypothetical entity; it is not anything. There is no possible world whose situation is nothingness. In other words, it would be meaningless if it is said that there is a possible world in which the situation is nothingness. "Nothing at all" is not a bizarre form of "something." It is not a situation "in" which something else "can" or "cannot" come to be. "Nothing" just means "not anything." Nothingness can only be defined negatively. That is, nothingness is not a non-existent entity or situation as the opposite state of something existent; rather it is the lack of everything, that is, the lack of all kinds of existents and existences. Nothingness has no reference at all.

Nozick (1981, p.123), therefore, contradicts himself when writes: "Onemight hold that nothingness as a natural state is derivative from a very powerful force toward nothingness, one any other forces have to overcome. Imagine this force as a vacuum force, sucking things into nonexistence or keeping them there. If this force acts upon itself, it sucks nothingness into nothingness, producing

something or, perhaps, everything, every possibility. Nothingness, hoisted by its own powerful petard, produces something."

Similarly, all these sentences are flatly contradictory:[1] "There are a variety of forms of nothing, [and] they all have physical definitions … The laws of quantum mechanics tell us that nothing is unstable … 70% of the dominant stuff in the universe is nothing … Nothing weighs something … Nothing is almost everything."[2]

In sum, phenomena such as quantum vacuum or quantum fields are physical realities and, therefore, clearly something, not nothing. Nothingness is neither a cause of something nor the effect of something. When there is not anything any question regarding cause and effect is meaningless. That is to say, the notions of cause and causation find their meaning only concerning existence and existents.

Creation

Creation traditionally means the making of a possible being that has not existed before. The non-existence of a possible being is not just not-existence in time, but it has a more general meaning; that is, a possible being is an essential contingent. In other words, even if a possible being is pre-eternal, it is still possible by itself; that is to say, it needs a cause to create it. Thus, creation is bringing into existence possible beings, whose existence or non-existence is not essentially necessary.

The definition of creation, however, is not as simple as it first seems. So, it would be better to grasp its meaning by comparing it to the notions which show only a kind of change (e.g., fabricating, transiting, forming, etc.). Creation is not any kind of these notions at all, since they imply the existence

1. All these quotations are from Krauss's videos posted on YouTube, including his Asimov Memorial "Nothing Debate" 1:20:25; American Atheists lecture 26:23; Richard Fidler interview; discussion with Richard Dawkins at Arizona State Origins Project 37min.; and Stockholm lecture 46: 37 (quoted from Craig 2023).
2. In his review of Krauss' book, *A Universe from Nothing*, David Albert (2012), a distinguished philosopher of quantum physics, writes, "vacuum states are particular arrangements of elementary physical stuff … the fact that some arrangements of fields happen to correspond to the existence of particles and some don't is not a whit more mysterious than the fact that some of the possible arrangements of my fingers happen to correspond to the existence of a fist and some don't. And the fact that particles can pop in and out of existence, over time, as those fields rearrange themselves, is not a whit more mysterious than the fact that fists can pop in and out of existence, over time, as my fingers rearrange themselves. And none of these poppings … amount to anything even remotely in the neighborhood of a creation from nothing … Krauss is dead wrong and his religious and philosophical critics are absolutely right."

of an enduring subject, which was not created. In other words, whenever there is a change there must be something thatchanges. All change requires an underlying material reality. Creation, on the other hand, is the radical causing of the whole existence of whatever exists. To cause something completelyto exist is not to produce a change in something, or to work on or with some already existing material; rather, to create is to give existence.

Moreover, in the beginning, in which there was not anything before, it is incoherent to characterize creation as a transition or change of something out of nothingness. So, when it is said that "the universe came into being out of nothing", it does not mean that there was a state of nothingness temporally prior to the origin of the universe from which the universe was created, but it simplyimplies that the universe lacks a prior physical cause belonging to its internal elements. As Narlikar (1977, p. 125) says: "The epoch t=0 is taken as the event of "creation". Prior to this state there existed no Universe, no observers, no physical laws. Everything suddenly appeared at t=0." But, to repeat, "prior to" the universe here does not mean "once upon a time before the beginning of the universe." The import of *creatio ex nihilo* is that there was not anything prior to the universe out of which it was made. So, philosophers by *creatio ex nihilo*are referring to the creation of the universe and the spontaneous generation of everything—space, time, matter, quantum/ vacuum fluctuations[1], natural laws, and so on—out of the depth of absolute non-existence, where nothing existed.[2]

Therefore, the creator of something out of nothing, to use Aristotelian terminology, is not only the efficient cause of its creature but also its material cause. This is an important point. For, the scientific models of the creation of the universe out of nothing should be able to show what they assume as the cause of the world is ontologically not only its efficient cause but also its material cause. That is to say, the models should explain the source of the matter and energy of the universe.

Scientific Explanation

I do not intend to repeat the rather long history of discussion and disagreement

1. As it was explained already, some physicists (Tryon (1973), Brout, Englert and Gunzig (1978), Grishchak and Zeldovich (1982), Atkatz and Pagels (1982), Gott (1982), and Vilenkin (1982, 1983, 1986)) have misleadingly found the solution of the problem of *creatio ex nihilo* in the phenomenon of quantum fluctuation.
2. Usingthe terms such as "from", "where", and the like to describe the non-existence is unavoidable. Clearly, they do not mean that the origin and the source of the universe are non-existence or that there is any place, state, or situation for nothingness.

among the philosophers of science concerning the nature and specifications of scientific explanation here. Instead, I only aim to emphasize what is meant by scientific explanationhere. According to most philosophers of science, what distinguishes "scientific explanation" from "mere description" is that the explanation of an event includes causal information relevant to the event. In other words, we want to know why the explanandum occurred instead of not occurring at all or occurring as one of the many possibilities. By a scientific explanation, we, therefore, try to find an adequate description of underlying causes helping to bring about the explanandum.

Moreover, the reason that I am focusing on causal explanation, rather than other versionsof explanations such as DN (Deductive Nomological), SR (Statistical Relevance), or theUnificationist models, is not merely that causal explanation is the best or has some privileges that the other versions of explanations do not have.[1] Rather, this decision is indeed the reflection of the view of those scientists who believe that science can answer not only the question of how the universe emerged billions of years ago but also the question of why there is a universe in which we live instead of some other universes or nothing at all. The why question here is not seeking a teleological response, but rather is trying to find what brought the whole universe into existence some billions of years ago. This question is indeed based on a highly intuitive principle according to which whatever comes into existence should have a cause.[2] Indeed, if scientists had not believed in this principle, they would not have tried to propose various modelsseeking that which was responsible for bringing the universe into existence.

Any physical model of the creation of the universe out of nothing, therefore, should be able to satisfy two conditions: (1) it should be able to explain why the universe came into existence; this is roughly seeking to find the efficient

1. The main objections against causal explanations are: (i) some explanations do not seem to be causal; (ii) there is too much causal history, and not all of causal history is explanatory; (iii) it is difficult to provide the resources for distinguishing those features of a causal process that are causally relevant to an outcome and those features that are irrelevant; (iv) causal relevance cannot be the whole story and the correct account will appeal to pragmatic factors involving the situation in which an explanation is requested (van Fraassen, 1980). It is clear that all these objections, if true, are irrelevant to the issue we are discussing here.
2. The quantum mechanical laws, even if they show that some behaviors of subatomic particles are uncaused (which is a highly questionable claim), do not constitute an exception to this principle. Quentin Smith (1988, p. 50) who has tried to argue in favor of "The Uncaused Beginning of the Universe" admits that the laws of quantum mechanics 'at most tend to show that acausal laws govern the change of condition of particles, such as the change of particle x's position from q_1 to q_2. They state nothing about the causality or acausality of absolute beginnings, of beginnings of the existence of particles'.

cause of the existence of the universe; (2) it should describe how the event of the creation happened; this is roughly equivalent to what Aristotle (*Physics* II3 and *Metaphysics* V2) calls the material cause of the universe. For the sake of argument, I assume that the material cause does not need to be only a physical entity. Rather, it can be any kind of ontological source of the existence of the universe. Since the laws of nature are scientists' devices to explain the *creatioex nihilo* of the world, they must satisfy the above two conditions.

The laws of natureand *creatio ex nihilo*

It seems that by saying that the laws of nature can explain the creation of the universe out of nothing, scientists implicitly consider the laws[1] as entities (the cause) thatwere responsible to bring the universe into existence some billions of years ago. As Paul Davies (1983, p. 217) says, "They [laws] have to be 'there' to start with so that the universe can come into being. Quantum physics has to exist (in some sense) so that a quantum transition can generate the cosmos in the first place."

At first glance, however, this seems to be absurd. For "the laws of physics do not themselves cause or constrain anything" (Craig 1991, p. 95); rather they are merely "descriptive statements of what occurs in nature" (Carroll 1988, p. 67). For the sake of argument, however, let us assume that by the laws of nature, scientists do not mean merely mathematical formulas, statements or descriptions; rather they mean that which instantiates the laws (as abstract or physicalentities) which have ontological power so that they can provide both efficient and material causes to create the world. Let us assume that there were such laws. The question is, are they sufficient to explain the creation of the universe out of nothing?

It should be noticed that this is not merely a question about the ability of the laws of nature that have been discovered already. Rather it is also about the ability of those laws of nature that we do not know anything about. By the laws of nature, I, therefore, mean all laws of nature that we have discovered, will discover, or even never discover (although in principle they are discoverable).[2] The only restriction here, *ex hypothesi*, is that the laws, even if they are considered as abstract independent entities, are something about the physical universe in which we live. That is, they should not be considered as

1. Of course, in addition to the laws, the scientific models usually assume the existence of some initial conditions too. For the sake of argument, I ignore this point here.
2. It should be noted that by law I only mean physical laws, not the rules of mathematics and logic, nor metaphysical and methodological principles.

some in principle unknowable and inaccessible entities which somehow exist somewhere, and are about the other worlds (if there are any such worlds). Considering these points, the claim of this paper is that even if the projects of the formulation of the "Grand Unified Theory"(GUT) or the "Theory of Everything' (TOE) become successful, and the most fundamental laws of nature are discovered, they would still not be able to provide an explanation of the emergence of the universe out of nothing. This problem basically remains out of the realm of science forever.

To explain the issue, assume that there are some fundamental scientific laws (*Ls*) that can explain the creation of the universe (*U*) out of nothing. The relationships between *Ls*and *U* would be one of the following possibilities:

I. *U* is ontologically prior to *Ls*, so *Ls* come after *U*.

II. *Ls* are ontologically prior to *U*, so *U* comes after *Ls*.

It should be noted that 'after' does not have a temporal meaning here; rather itonlyindicates an ontological or causal priority.[1] ccording to this kind of priority, to say thatx is ontologically prior to *y* is to say that *x* can exist without *y*, whereas *y* cannot exist without *x*. Or, in other words, "to say that *x* is ontologically prior to *y* is to say that (1) *y* is dependent on *x* for its existence, and (2) *x* is not dependent on *y* for its existence" (Gorman, 1993, p. 461). For example, the existence of the motion of my fingers when I type depends on my existence, but not vice versa.[2] Now, regarding this definition let us examine the above-mentioned options (I) and (II).

1. Option (I) maintains that *Ls* are derived and emerged from *U*. *Ls* are none other than facts about the properties of *U* or the relations among those properties. *Ls*, of course, can be considered ontologically independent of *U*, or supervenient on it. We can even assume that, as positivists believed, *Ls* is a kind of unrestricted regularity that exist between some aspects of *U*.

The important point, however, is that, ontologically, *U* comes first and *Ls* next, so the former serves as the ontological ground for the latter. It is true that, in thiscase, the properties of *U* constitute truth-makers for *Ls* describing the behavior of *U* in the circumstances of its emergence. *Ls*, however, cannot be the cause of the existence of *U*, and can never explain why and how *U* comes into existence if *U* is the ontological origin of *Ls*.

There might, however, be one other way before the proponent of option (I).

1. So, the implications of the case in which *U* and *Ls* come along together into existence are similar to the implications of option (1) (see also the next footnote).
2. It is clear that if *x* is ontologically prior to *y*, then y can never be temporarily prior to *x*. So, either x is temporarily prior to *y*, or they exist simultaneously.

She may assume that the chain of explanations needs not to be assumed linear; rather, natural phenomena can be explained by a circular coherent chain of merely scientific explanations. This is similar to what coherentists have proposed in epistemology to find a justification for human knowledge. According to such a circular explanation, *Ls*can explain the *creatio ex nihilo* of *U* even if *Ls* comes into existence after *U*. For example, consider a case in which *Ls* suggest that *U* can create itself.[1] Through a circular causal chain, then, *Ls* would explain the coming into existence of *U*, and *U* would be the cause of the instantiation of *Ls*.

Apart from the fact that coherentism has not been a successful project in epistemology, the analogy between the justification of knowledge and scientific explanation is false. Firstly, because, despite all the skeptical views, scientists still rightly believe that there is a real chain of causes and effects in nature, and the aim of scientific theories is the explanation of causal relationships. This chain of relations must be linear since however big the chain is, it is ontologically impossible that the chain of 'real' causes and effects is circular, in one which the existences of entities depend on each other in a circular way. Indeed, in such an imaginary circular chain any entity would be both the cause and effect of itself.

Furthermore, even if there were such a circular chain of events in the universe — and it is unclear how this could be — and even if we ignore the absurdity of the idea of something being its own cause, the circular causal chain cannot be applied to the universeasawhole. Because option (I) is based on the Big Bang model. According to this model, the whole of that imaginary loop, including matter, space, time, natural laws, and so on has been created out of nothing. In such an absolute nothingness, *ex hypothesi*, there was neither *U*, nor *Ls*, nor anything else. So, it is unclear how something which did not exist yet can be a cause or an effect. At any rate − whether there is a causal loop in the universe or not − the emergence of the whole universe starts from an initial point, and consequently, the explanation of this emergence should be started from an initial point and continues in a linear chain, not in a circular one.

Indeed, in the case of option (I), it would certainly sound contradictory if anybody claims that he has presented a scientific model for the explanation of the creation out of nothing. The reason is very straightforward: If everything came into existence after the Big Bang, then one cannot provide a natural causal explanation for the initial event. As Grunbaum (1991, p. 238-239)

1. Smith (1999) discusses sympathetically such a highly questionable suggestion.

rightly points out, to postulate a physical cause of the Big Bang is simply to contradict the theory. The contradiction can be shown as follows:

i. *Ls* can explain the creation of *U* out of nothing.

ii. Scientific explanation, at least for the issue at hand, means finding a causal relationship between two phenomena.

iii. Therefore, *Ls*are the cause that brought *U* into existence.

iv. *Ls*, as the cause of *U*, should exist prior to *U*.

v. *Ls*, *ex hypothesi*, come after *U*. (According to the Big Bang Model, there was nothing (whether matter, time, space, physical laws, or anything else) whatsoever that could precede[1] the Big Bang.)

vi. Contradiction.

2. Contrary to option (I), option (II) does not have incoherent consequences. It assumes that *Ls* precede *U* as if *Ls* are imposed "from above" upon *U*, instead of arising from "bottom-up." Option (II) is not compatible with the view that laws are nothing but regularities among objects. Rather it can be compatible with the Armstrong-Dretske-Tooley Theory, according to which, *Ls* are objective relations, not between objects, but between properties or universals they instantiate. These relations either are restricted to the instantiated universals (Armstrong, 1980 & 2016), or there can even be uninstantiated universals and, hence, uninstantiated laws in a kind of Platonic world (Tooley, 1977). Option (II) can also be compatible with the view of those philosophers like Bigelow et al. (1992), Ellis and Lierse (1994), and Ellis (2001) who believe that the laws of nature are facts about dispositional nomic properties essentially possessed by natural kinds of objects.

Whether *Ls* are contingently imposed upon *U* or necessarily, the crucial point is that the identity of *Ls* should be quite independent of *U*'s; that is to say, ontologically, *Ls* exist prior to and independent of *U*. *Ls*, therefore, according to this view, can causally be the responsible for bringing *U* into existence. In this case, the crucial question is, what kind of entities are *Ls*?

Two scenarios are imaginable:First, *Ls* are contingent entities that appeared with singularity out of nothing. This scenario, however, is untenable. Because the main problem arises again: how the *creatio ex nihilo* of the laws can be explained? Was it an uncaused event?Or were there other laws responsible for this creation, which themselves were created by another generation of the laws … *ad infinitum*? None of these are satisfactory.

The second scenario is that *Ls* are eternal entities in a platonic world, with

1. As we explained already, this is of course not a temporal precession, rather it means ontological priority.

ontological power. Although it seems to be unlikely that this scenario of option (II) is the favorable option for scientists like Hawking, some philosophers, recognizing the problems of option (I), have found it desirable. Quentin Smith, for example, has taken this position concerning quantum cosmology scenarios. While Hawking himself rejects platonic realism, Smith (1998b, p. 99) asserts that "one must separate Hawking's vague and inconsistent philosophical speculations from his rigorous mathematical cosmology." He (1998, p. 78) believes that "to make sense of the unconditional probabilities implied by quantum-gravity cosmologies[1] [two axioms should be presupposed:] there are possible worlds in the above-specified sense and … there are Tooley-like laws of nature." Therefore, "Vilenkin's, and Hartle and Hawking's, cosmologies require a Platonic-realist theory of laws of nature" (Smith, 1998, p. 82).

In this case, however, the creation of the world would be from something, not out of nothing. So, this scenario is out of the scope of our discussion. Let us, however, analyze this scenario as a complement to our discussion.

This scenario faces a problem that arises from the situation of the world in the Big Bang singularity and also before the Plank time. Since the classical notions of space and time and all known laws of physics break down at the singularity, they play no role prior to 10^{-43} seconds after the singularity.[2] This result is based on the predictions of general relativity, according to which, at the very start of the universe, as the dimensions of space became zero, then time was too inclined towards zero, owing to the fact that space, time, and matter are all interrelated. Thus, the laws of science broke down because they have all been formulated on the basis of time and space.

Indeed, neither general relativity nor quantum mechanics can currently describe the earliest moments of the Big Bang. In P.C.W. Davies's (1978, pp. 78-79) words: "We cannot continue physical reasoning, or even the concept of spacetime through such an extremity [i.e., singularity] ... causality and sequence break down altogether at a singularity." Similarly, Hawking (1976, p. 2460) writes: "A singularity is a place where the classical concepts of space and time break down. this breakdown is not merely a result of our ignorance

1. It is worth mentioning that "we know, from elementary quantum mechanics, that it is literally inconsistent (i.e., leads to contradictions) to treat a wave function as giving probabilities in an absolute sense" (Halvorson & Kragh, 2021). For the sake of argument, however, I ignore this obvious problem in Smith's idea.
2. Singularity should not be confused with the Planck era which is the duration up to 10^{-43} sec after the Big Bang, whose description requires the marriage of GTR and quantum theory to yield a quantum theory of gravitation. The most promising candidate for such a unified theory is the String Theory.

of the correct theory but that it represents a fundamental limitation to our ability to predict the future, a limitation that is analogous but additional to the limitation imposed by the normal quantum-mechanical uncertainty principle."

It is worth mentioning that, since 1965, in which Hawking and Penrose showed that the universe must have a singularity, several models have been proposed to avoid the singularity and absolute beginning.[1] However, as Craig and Sinclair (2012) have shown, the history of 20th-century cosmogony has seen a parade of such failed theories. In 2003 Arvind Borde, Alan Guth, and Alexander Vilenkin showed that any universe which is, on average, in a state of cosmic expansion throughout its history must have a beginning. Later, Vilenkin (2015) wrote that "we have no viable models of an eternal universe, " and that "all the evidence we have says that the universe had a beginning" (Vilenkin, cited in Grossman, 2012).

Arguably, in this subject, the best model is the string theory, which "seems to rule out singularities of infinite curvature or spatial length shrinking to zero." (Halvorson & Kragh, 2021). However, it is not the case that String Theory necessarily effaces singularities (Roiban, 2006). Moreover, according to this theory, our universe has emerged not out of nothing, but from a "pre-big-bang universe" (Gasperini, 2008). So, the String Theory is out of the scope of our topic.

It seems, therefore, that in all models of the *creatio ex nihilo* the singularity of the universe is unavoidable. In this case, it would be impossible to formulate the pre-Big Bang incident (and the Big Bang itself) and to demonstrate a model of it, using the laws of nature. Considering this limitation of the initial singularity, Smith (1992, pp. 222-223) concludes that in principle, no physical laws govern what happens in the Big Bang singularity, and that "[t]here is no law, not even a probabilistic law, governing the singularity... Deterministic or even probabilistic laws cannot obtain on the quantum level in the singularity, since there is no quantum level in the singularity; the space-time manifold that quantum processes presuppose has broken down. The singularity is a violent, terrifying caldron of lawlessness." Also, such a strange nature of the initial singularity leads Paul Davies (1981, p. 161) to the

1. For example, the first model was the model of the inflationary universe which was popular in the 1980s. (Linde, 1984) However, Borde and Vilenkin (1994, p. 3305) showed that "a physically reasonable spacetime that is eternally inflating to the future must possess an initial singularity." In response, Linde (1994, pp. 1783-1826) accepted their conclusion. The other one which avoids the singularity is the Hawking-Hartle (1983) Model. This model, however, suffers from some problems that make it unpalatable. For more discussion on this model, see Craig & Smith (1995), Deltete & Guy (1997), Craig (1997), and Smith (1998).

conclusion that "anything can come out of a naked singularity."

Smith's and Davies's conclusions, however, seem to be too radical. For, the fact that the spatial-temporal laws of nature cannot be applied to the singularity or the events before 10^{-43}, does not imply that those events are lawless or that there was no causal relationship between those events and eras and what happened after the singularity and the Plank time. Nor does it mean that the Big Bang was an uncaused, lawless event. After all, as Smith (1988, p. 45) himself asserts "the singularity at to... is a source of the universe." That is to say, it is an undeniable fact that the Big Bang singularity is the source of all of what happened next. This is the most obvious paradigm of a causal relationship.

At any rate, let us assume that there was a singularity in which all the laws of physics were broken down. This means that "[t]he universe will evolve from the Big Bang, completely independently of what it was like before … Events before the Big Bang, are simply not defined because there's no way one could measure what happened at them" (Hawking, 2014). In other words, the nature of the Big Bang singularity shows that the events and phenomena should be divided into two distinct groups which are essentially different: what existed and happened (1) prior to or in the singularity (or before the Plank time), and (2) after the singularity (or after the Plank time).

This distinction implies at least two points: (1) epistemologically, it shows the limitation of human ability to formulate the related laws and to predict what happened, or could have happened, in the Big Bang. Those events are inherently unpredictable. (2) Ontologically, it implies that the nature of laws governing the behavior of the singularity or prior to it is essentially different from the laws of the world in which we live. Therefore, if there were any such laws prior to the universe, it is, in principle, utterly unknowable what kind of laws they could be.

Considering the above points, the proponent of option (II) has to accept that:

i. In the so-called platonic world there are two kinds of independent physical laws, *Ls*and *Ls**.

ii. *Ls* govern what happened after the singularity (or after the Plank time), and *Ls** govern the behavior of the singularity and prior to it (or before the Plank time).

iii. Since *Ls* and *Ls** explain two essentially different physical situations, they represent two essentially different physical laws.

iv. Therefore, either (a) there cannot be any such physical law that bridges between Lsand *Ls** (or govern both of them), or (b) if there is any such law (L_b) it can only govern the very general common aspects of *Ls* and *Ls**. (For

example, L_b can be some general metaphysical rules such as: neither *Ls* nor *Ls** violate the rules of logic and mathematics; the singularity is the ontological source and material cause of the universe, and so forth).

v. To explain the *creatio ex nihilo* of the world scientists need to appeal to *Ls**.

vi. *Ls** are in principle inaccessible and unknowable.

vii. Therefore, a scientific explanation of the creation of the universe out of nothing by appealing to the physical laws of nature is essentially impossible.

Some short points about the above argument:

1. *Ls** and *Ls* are physical laws. That is to say, even if they can have abstract instantiations, they still represent and explain the physical (concrete) aspects of the concrete world.

2. *Ls** and *Ls*, therefore, have nothing to do with metaphysical principles or the rules of logic and mathematics.

3. Premise (**vi**) shows only the physical impossibility of having any access to or knowing the laws *Ls**. This is similar to the inaccessibility of the laws of other worlds in the oscillating universe model or infinitely parallel universes. Of course, this physical impossibility is a sufficient reason to prevent physicists from presenting any physical model for the *creatio ex nihilo* of the world.

4. However, none of the above arguments prevents philosophers from theorizing philosophically about the creation of the universe out of nothing. All they need are some general laws and rules (such as L_b) which are common among all physical and metaphysical situations. This is not merely an arbitrary option between science and philosophy. Rather it means if the creation of the universe out of nothing should be explained, then the consequence of modern cosmology is that it can only be explained metaphysically, and not scientifically.

Conclusion

Kant (B454-B462) in his discussion of the first antinomy of pure reason argued that the problem of temporal and spatial finitude or infinitude of the universe cannot be solved metaphysically. Now, it seems modern cosmology has dissolved the antinomy in favorof the spatial and temporal finiteness of the world. Ironically, on the other hand, modern cosmology has produced the problem of *creatio ex nihilo* which cannot be explained scientifically. Here philosophers should discuss and decide whether (a) the creation of the universe out of nothing is a brute unexplainable fact, or (b) if there were some prior realities from which the universe originated. Whichever of these options is chosen, the crucial point is that — however the demarcation between

science and philosophy is made — all of the options are merely metaphysical solutions, and discussion about them and selection of one of them are beyond the realm of science and belong to the domain of philosophy. The *creatio ex nihilo* of the universe cannot be explained by appealing to the laws of nature, and it will always remain beyond the domain of purely experimental science. As Isham (1992, p. 4) emphasizes: "Note that the one question which even a very ambitious creation theorist cannot (or, perhaps, should not) address is 'why is there anything at all?' That is strictly a job for philosophers and theologians!"

Ethics declarations

Conflict of interests

The author has no competing interests.

References

Albert, D. (2012). On the origin of everything. Critical notice of *A Universe from Nothing* by Lawrence Krauss. *New York Times Sunday Book Review*.

Aristotle (1998). *The metaphysics* (H. Lawson-Tancred, Trans.). Penguin.

Aristotle (1996). *Physics* (R. Waterfield, Trans.). Oxford University Press.

Armstrong, D. (1980). *Nominalism and realism: universals and scientific realism*, vol. 1. Cambridge University Press.

Armstrong, D. (2016). *What is a law of nature?* (Reissue edition). Cambridge University Press.

Atkatz, D., & Pagels, H. (1982). Origin of the universe as a quantum tunneling event. *Physical Review*, D25, 2065-2073. https://doi.org/10.1103/physrevd.25.2065

Barrow, J. & Tipler, F. J. (1996). *The anthropic cosmological principle*. Oxford University Press.

Bigelow, J., Ellis, B., & Lierse, C. (1992). The world as one of a kind: natural necessity and laws of nature. *British Journal for the Philosophy of Science*, 43, 371-88. https://doi.org/10.1093/bjps/43.3.371

Bojowald, M. (2010). *Zurück vor den urknall, English translation: Once Before Time: A Whole Story of the Universe.* Knopf.

Bondi, H. (1961). *The Universe at Large*. Heinemann.

Bondi, H. (2010). *Cosmology* (2nd ed.). Cambridge University Press.

Bondi, H., & Gold, T. (1948). The steady state theory of the expanding universe. *Monthly Notices of the Royal Astronomical Society,* 108(1948), 252-270. https://doi.org/10.1093/mnras/108.3.252

Borde, A., & Vilenkin, A. (1994). Eternal inflation and the initial singularity. *Physical Review Letters*, 72, 3305-3308. https://doi.org/10.1103/PhysRevLett.72.3305

Borde, A., Guth, A., & Vilenkin, A. (2003). Inflationary spacetimes are incomplete in past directions. *Physical Review Letters*, 90, 151301. https://doi.org/10.1103/PhysRevLett.90.151301

Brout, R., Englert, F., & Gunzig, E. (1978). The creation of the universe as a

quantum phenomenon. *Annals of Physics* (N.Y.), 115, 78-106. https://doi.org/10.1016/0003-4916(78)90176-8

Brush, S. J. (1992). How cosmology became a science? *Scientific American*, 267(2), 62-71. https://doi.org/10.1038/scientificamerican0892-62

Carroll, W. E. (1988). Big Bang cosmology, quantum tunneling from nothing, and creation, "*Laval theologique et philosophique*, 44, 1 (fevrier 1988). https://doi.org/10.7202/400359ar

Craig, W. L. (1991). The existence of God and the beginning of the universe. *Truth: A Journal of Modern Thought*, 3, 85-96. URL = <https://personal.lse.ac.uk/ROBERT49/teaching/ph103/pdf/Craig_KalamCosmologicalArgument.pdf>.

Craig, W. L. (1997). Hartle-Hawking cosmology and atheism. *Analysis*, 57, 291-295. URL = <https://www.jstor.org/stable/3328091>

Craig, W. L. (2023). Creation *ex nihilo*: theology and science. *Reasonable Faith*. URL = <https://www.reasonablefaith.org/writings/popular-writings/existence-nature-of-god/creation-ex-nihilo-theology-and-science>

Craig, W. L., & Q. Smith (1995). *Theism, Atheism, and Big Bang Cosmology*. Oxford University Press.

Craig, W. L., & Sinclair, J. (2012). On non-singular spacetimes and the beginning of the universe. In Y. Nagasawa (Ed.), *Scientific Approaches to the Philosophy of Religion. Palgrave Frontiers in Philosophy of Religion*, (pp. 95-142). Macmillan.

Davies, P. C. W. (1978). Space-time singularities in cosmology and black hole evaporation. In J. T. Fraser, N. Lawrence, & Clark (Eds.), *The Study of Time III.* Springer-Verlag.

Davies, P. C. W. (1981). *The edge of infinity*. Simon and Schuster.

Davies, P. C. W. (1983). *God and the new physics*. Penguin Books.

Deltete, R., & Guy, R. (1997). Hartle-Hawking cosmology and unconditional probabilities. *Analysis*, 57, 304-315. https://doi.org/10.1093/analys/57.4.304

Descartes, R. (1984/1991). *The philosophical writings of descartes*, vols. 1-3 J. Cottingham, R. Stoothoff, D. Murdoch, & (for vol. 3) A. Kenny, Trans. & Eds.). Cambridge University Press.

Drees, W. (1988). Beyond the limitations of the Big Bang Theory: cosmology and theological reflection. *Bulletin of the Center for Theology and the*

Natural Sciences, 8.

Drees, W. (1990). *Beyond the Big Bang: quantum cosmologies and God*. Open Court.

Drees, W. (1991). Quantum cosmologies and the 'beginning.' *Zygon*, 26, 373-396. https://doi.org/10.1111/j.1467-9744.1991.tb00825.x

Ellis, B. (2001). *Scientific Essentialism*. Cambridge University Press.

Ellis, B., & Lierse, C. (1994). Dispositional essentialism. *Australasian Journal of Philosophy*, 72, 27-45. https://doi.org/10.1080/00048409412345861

Ellies, G. (1993). *Before the beginning: cosmology explained.* Boyars-Bowerdean.

Gasperini, M. (2008). *The universe before the Big Bang: cosmology and String Theory.* Springer.

Gorman, M. M. (1994). Ontological priority and John Duns Scotus. *Philosophical Quarterly, Special Issue: Philosophers and Philosophies*, 43(173), 460-471. https://doi.org/10.2307/2219986

Gott, J. R. (1982). Creation of open universes from de sitter space. *Nature*, 295, 304-307. https://doi.org/10.1038/295304A0

Grishchak, L. P., & Zeldovich, Y. B. (1982). Complete cosmological theories. InM. J. Duff & C. J. Isham (Eds.), *Quantum Structure of Spaceand Time*, (pp. 409-422). Cambridge University Press.

Grossman, L. (2012). Why physicists can't avoid a creation event. *New Scientists* (January 11, 2012).

Grünbaum, A. (1989). The pseudo-problem of creation in physicalcosmology. *Philosophy of Science*, 56(3), 373-394. https://doi.org/10.1086/289497

Grünbaum, A. (1991). Creation as a pseudo-explanation in current physical cosmology. *Erkenntnis*, 35, 233-254. https://doi.org/10.1007/bf00388287

Grünbaum, A. (1993). Narlikar's "creation" of the Big Bang universe was a mere origination. *Philosophy of Science*, 60(4), 638-646. https://doi.org/10.1086/289764

Grünbaum, A. (1994). Some comments on William Craig's "creation and Big Bang cosmology". *Philosopia Naturalis*, 31(2), 225-236. URL = <https://infidels.org/library/modern/adolf-grunbaum-comments/>

Grünbaum, A. (1998). Theological misinterpretations of current physical cosmology. *Philo*, 1(1), 15-34. https://doi.org/10.5840/philo1998113

Halvorson, H., & Kragh, H. (2021). Cosmology and theology. *The Stanford*

Encyclopedia of Philosophy (Winter 2021 Edition), Edward N. Zalta (Ed.). URL = <https://plato.stanford.edu/archives/win2021/entries/cosmology-theology>.

Hartle, J. B., & Hawking, S. W. (1983). Wave function of the universe. *Phys. Rev. D*, 28(12), 2960-2975. https://doi.org/10.1103/PhysRevD.28.2960

Hawking, S. W. (1976). Breakdown of predictability in gravitational collapse. *Physical ReviewD*, 14, 2460. https://doi.org/10.1103/physrevd.14.2460

Hawking, S. (2014). The beginning of time. In *Stephen Hawking: The Official Website*. Cambridge: Cambridge University. (Archived from the original on 6 October 2014. Retrieved 26 December 2012.)

Hawking, S., & Ellis, G. F. R. (1965). Singularities in homogenous world models. *Physical Letters*, 17, 246-247. https://doi.org/10.1016/0031-9163(65)90510-X

Hawking, S., & Mlodinow, L. (2010). *The Grand Design*. Bantam Books.

Hoyle, F. (1948). A new model for the expanding universe. *Monthly Notices of the Royal Astronomical Society*, 108, 372-82. https://doi.org/10.1093/mnras/108.5.372

Hoyle, F. (1975). *Astronomy and cosmology: amodern course*. W. F. Freeman & Co.

Hoyle, F. (1992). Light element synthesis in Planck fireballs. *Astrophysics and Space Science*, 198, 177- 193. https://doi.org/10.1007/bf00644753

Hoyle, F. (1994). *Home is where the wind blows: Chapters from a cosmologist's life*. University Science Books.

Ibn-Sina. (2000). *al-Esharat va al-Tanbihat*, Vol 3. Daftar Nashre Katab.

Isham, C. (1992). Quantum theories of the creation of the universe. Quoted from Craig, The caused beginning of the universe: a response to Quentin Smith. *British Journal for the Philosophy of Science* 44, 623-639. https://doi.org/10.1093/bjps/44.4.623

Isham, C. (1994). Quantum cosmology and the origin of the universe. Lecture presented at the *Cosmos and Creation Conference*. Cambridge University, 14 July 1994.

Kant, I. (2003/1929). *Critique of pure reason* (N. Kemp Smith, Trans.). Palgrave Macmillan.

Kragh, H. (2007). *Conceptions of cosmos: From myths to the accelerating universe: ahistory of cosmology*. Oxford University Press.

Kragh, H. (2023). Cosmology and religion. *Encyclopedia of the history of science* (January 2020). Accessed 12th March 2023. URL = <https://ethos.lps.library.cmu.edu/article/id/37/>.

Linde, A. (1984). The inflationary universe. *Reports on Progress in Physics*, 47, 925-86. https://doi.org/10.1088/0034-4885/47/8/002

Linde, A., Linde, D., & Mezhlumian, A. (1994). From the Big Bang Theory to the theory of astationary universe. *Physical ReviewD*, 1783-1826. https://doi.org/10.1103/physrevd.49.1783

Mousavi Karimi, M. (2011). Adolf Grünbaum on the Steady-State Theory and *CreatioContinua* of matter out of nothing. *Zygon.* 46(4), 857-871. https://doi.org/10.1111/j.1467-9744.2011.01221.x

Mousavi Karimi, M. (2023). Quantum fluctuation and critical analysis of the physical approach to the creatio ex nihilo of the universe. *International Multidisciplinary Journal of Pure Life* (to be published).

Mulla-Sadra. (1981). *Hikmat al-Muta'aliya fi-l-Asfar al-'Aqliyya al-Arba'*a. Vol. 1-9. Dar Ehya al-Torath al-Arabi.

Munitz, M. K. (1974). *Existence and logic*. New York University Press.

Narlikar, J. (1977). *The structure of the universe*. Oxford University Press.

Nozick, R. (1981). *Philosophical explanations*. Harvard University Press.

Penrose, R. (1965). Gravitational collapse and space-time singularities. *Phys. Rev. Lett.* 14, 57. https://doi.org/10.1103/PhysRevLett.14.57

Penrose, R. (2006). Before the Big Bang: An outrageous new perspective and its implications for particle physics. *European Particle Accelerator Conference* (EPAC 06), (pp. 2759-2762). Edinburgh, Scotland.

Penrose, R. (2010). *Cycles of time: An extraordinary new view of the universe.* Bodley Head.

Roiban, R. (2006). Singularities, effective actions and String Theory. Talk given at the conference "*Quantum gravity in the Americas III*, 24–26, Aug 2006, at the Institute for Gravitational Physics and Geometry, Penn State University. [Slides of the talk are available online.]

Rovelli, C. (2010). *Quantum gravity*. Cambridge University Press.

Smith, Q. (1988). The uncaused beginning of the universe. *Philosophy of Science*, 55, 39-57. https://doi.org/10.1086/289415

Smith, Q. (1992). A Big Bang cosmological argument for God's nonexistence.

Faith and Philosophy, 9(2), 217-237. https://doi.org/10.5840/faithphil19929215

Smith, Q. (1994a). Can everything come to be without a cause? *Dialogue: Canadian Philosophical Review*, 33, 313-324. https://doi.org/10.1017/s0012217300010568

Smith, Q. (1994b). Did the Big Bang have a cause? *British Journal for the Philosophy of Science*, 45, 649-668. https://doi.org/10.1093/bjps/45.2.649

Smith, Q. (1998). Why Steven Hawking's cosmology precludes a creature. *Philo*, 1(1), 75-93. https://doi.org/10.5840/philo1998117

Smith, Q. (1998b). Swinburne's explanation of the universe. *Religious Studies*, 34, 91-102. https://doi.org/10.1017/s0034412597004228

Smith, Q. (1999). The reason the universe exists is that it caused itself to exist. *Philosophy*, 74, 579-586. https://doi.org/10.1017/s0031819199000686

Steinhardt, P. J., & Turok, N. (2007). *Endless universe: beyond the Big Bang*. Doubleday.

Tooley, M. (1977). The nature of laws. *Canadian Journal of Philosophy*, 7, 667-98. https://doi.org/10.1080/00455091.1977.10716190

Tryon, E. P. (1973). Is the universe a vacuum fluctuation? *Nature*, 246, 396-397. https://doi.org/10.1038/246396a0

Van Fraassen, B. C. (1980). *The scientific image*. Clarendon Press.

Vilenkin, A. (1982). Creation of universe from nothing. *Physics Letters*, 117B, 25-28. https://doi.org/10.1016/0370-2693(82)90866-8

Vilenkin, A. (1983). Birth of inflationary universes. *Phys. Rev. D*, 27, 2848-2855. https://doi.org/10.1103/physrevd.27.2848

Vilenkin, A. (1986). Quantum cosmology and the initial state of the universe. *Phys. Rev. D*, 37, 888-897. https://doi.org/10.1103/physrevd.37.888

Vilenkin, A. (2015). The beginning of the universe. *Inference: International Review of Science,* 1(4). URL = <https://inference-review.com/article/the-beginning-of-the-universe>.